GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL
[ ] REVISION NO. ______

Project No. A-2884 DATE: 6/26/81

Project Director: J. C. Butterworth MISC ~~School~~/Lab RAIL/RED

Sponsor: Netherlands Government Publishing Office

Type Agreement: Contract No. 60/Dir/Eck

Award Period: From 3/4/81 To ~~10/4/81~~ 11/18/81 (Performance) -- (Reports)

Sponsor Amount: $47,998 Contracted through:

Cost Sharing: None GTRI/GIT

Title: Development and Delivery of a 94 Ghz Radar EIO Modulator

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ADMINISTRATIVE DATA OCA CONTACT William F. Brown

1) Sponsor Technical Contact: Mr. J. G. den Breems

2) Sponsor Admin./Contractual Contact: Mr. G. A. Eckhardt, Head Legal Dept.,Netherlands Government Purchasing Office; P. O. Box 10200, 800 GE Zwolle, Holland

Reports: See Deliverable Schedule Security Classification: None

Defense Priority Rating: None

RESTRICTIONS

See Attached -- Supplemental Information Sheet for Additional Requiremen

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with None proposed

COMMENTS: Payment will be obtained through documentary credit account with Trust Company Bank of Atlanta. See special invoicing instructions in Financial Data Sheet

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GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date June 1, 1983

Project Title: Development & Delivery of a 94 GHz Radar EIO Modulator

Project No: A-2884

Project Director: J. C. Butterworth

Sponsor: Netherlands Gov't Publishing Office

Effective Termination Date: 11/18/81

Clearance of Accounting Charges: 11/18/81

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ____________

Assigned to: RAIL/IMD (~~School~~/Laboratory)

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FORM OCA 10:781

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

29 June 1981

Physisch Laboratorium TNO
Oude Waalsdorperweg 63
2597 AK 's-GRAVENHAGE
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Progress Report Number 1 under Contract No. 60/Dir/Eck Covering the Period 4 March 1981 to 31 March 1981

Gentlemen:

This monthly progress letter summarizes the activities on the above referenced contract during the month of March, 1981. Early in the month, activities centered around investigating the basic modulator design. Once a definite idea of the circuitry required to meet the specifications listed in the proposed program was formulated, the electronic development was begun. In conjunction with the electronic development of the required circuitry, the major hardware items were ordered to meet the scheduled time for testing and final construction.

Electronic Development

As a result of the electronic development efforts during the month, it was determined that two readily available monostable multivibrators were required to generate the low level drive pulse. By this method very fast rise and fall times were obtained with the required variable pulse width centered around 100 ns. This pulse will then be used to drive a network of VMOS FET transistors which have very fast rise and fall times, and which supply the current to drive the hard tube modulator.

Physical Configuration

Several physical configurations of the modulator were considered during the month. In order to protect the TTL and other low voltage components from stray RF fields due to the high voltage, the pulse shaping network and other circuitry is to be installed in the control console. A physical model of the modulator was constructed in order to determine the best electronic design, the minimum size, and the most favorable physical arrangement possible.

Financial Status

The expenditures for the month of March are $4,952 for materials and personal services.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

JAB:jct

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-288

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

7 August 1981

Physisch Laboratorium TNO
Oude Waulsdorperweg 63
2597 AK's-Gravenhage
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 2 on Project A-2884, Contract 60/Dir/Eck Covering the Period 1 April to 30 April 1981

Gentlemen:

The results and current status or work performed on the subject contract during the referenced performance period are summarized below.

Regenerative Switch

Utilizing the well known blocking oscillator technology and applying it to modern high voltage microwave planar triode vacuum tubes has resulted in the development of a regenerative circuit which serves as a rapid-acting switch. The basic operation of the circuit is as follows: after exciting a planar triode into conduction by means of FET or bipolar transistors, part of the cathode current is fed back into the grid in phase by means of a current transformer, thereby forming a positive feedback or regenerative network. This rapid turn-on drives the tube hard into saturation which provides both an extremely rapid rise-time and a very flat top of the pulse. In addition, a large savings in parts is incurred and hence a reliability increase is attained.

Tube Filament Power Supplies

Due to the high voltages present in the planar triodes and the EIO, and the fact that the cathode and filament are interconnected, it is necessary to have the filament supply float at least at the highest voltage present. In addition to this requirement, it was also found necessary that for the regenerative circuitry, as described above, to function properly, that the filament supply have as low as possible stray capacity in order to maximize the amount of current utilized for the regenerative process. These two requirements necessitated the development of a specialized power supply to provide the filament voltage for both the regenerative planar triodes and the EIO.

Financial Status

Expenditures on Contract 60/Dir/Eck in March were $4,953 while expenditures in April were $8,200. Expenditures on the contract are thus approximately $13,153 leaving $34,845 on the contract as of 31 April 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-2884

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

13 August 1981

Physisch Laboratorium TNO
Oude Waulsdorperweg 63
2597 AK's-Gravenhage
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 3 on Project A-2884, Contract 60/Dir/Eck Covering the Period 1 May to 31 May 1981

Gentlemen:

The results and current status or work performed on the subject contract during the referenced performance period are summarized below.

Regenerative Switch Modification

The utilization of regeneration in order to provide extremely fast hard tube turn-on times has resulted in an efficient and quite reliable high voltage pulse source. Its source of excitation was modified this month by utilizing high current density varistors, an advanced semiconductor technology outgrowth.

The hard tube cut-off bias is held by the varistor which has a VMOS FET in parallel with it. By turning the FET on into saturation, the varistor is shorted out, zero-biasing the hard tube thereby driving it rapidly into saturation. This new development has simplified the regenerative switch circuit even further, making it highly reliable.

Control Console

As required for the final product, work began on the construction of the control console which will provide the necessary signals and voltages in order to operate the modulator. A prefabricated box assembly was found appropriate to include the necessary meters to monitor EIO transmit-time and beam current, the associated protective circuit, and required power supplies. An internal pulse-control circuit board, when synchronized with an external signal generator, will provide the required pulse to drive the modulator.

Financial Status

Expenditures on Contract 60/Dir/Eck in May were $8,748. Expenditures on the contract are thus approximately $21,932 leaving $26,066 on the contract as of 31 May 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

JCB:pmw

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-2884

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

27 August 1981

Physisch Laboratorium TNO
Oude Waulsdorperweg 63
2597 AK's-Gravenhage
The Netherlands

Attention: Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 4
on Project A-2884, Contract 60/Dir/Eck
Covering the Period 1 June to 30 June 1981

Gentlemen:

The results and current status of work performed on the subject contract during the referenced performance period are summarized below.

Printed Circuits

As desired for inherent stability, maintenance, and appearance, printed circuit boards were designed and constructed to hold the discreet components for the modulator and control console. As discussed in the technical review, the parasitic capacity and inductance had to be held to a minimum in the layout of the printed circuit boards to decrease the rise-time of the generated pulse. Printed circuit boards will be utilized in the low voltage pulse driver, regenerative high voltage driver, tailbiter, tube filament power supplies, and control console circuits.

Boxes

During the technical review held this month it was learned that AEG container boxes were to be utilized to enclose the modulator and control console. This decision required some modifications to both the modulator and control console construction which is in progress.

Financial Status

Expenditures on Contract 60/Dir/Eck in June were $8,739. Expenditures on the contract are thus approximately $30,600, leaving $17,326 on the contract as of 30 June 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

JCB:pmw

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-2884

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

27 August 1981

Physisch Laboratorium TNO
Oude Waulsdorperweg 63
2597 AK's-Gravenhage
The Netherlands

Attention: Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 5 on Project A-2884, Contract 60/Dir/Eck Covering the Period 1 July to 31 July 1981

Gentlemen:

The results and current status of work performed on the subject contract during the referenced performance period are summarized below.

Modulator Box

As discussed in the Technical Review held in June 1981, the AEG-TELEFUNKEN box served to set the 17.55 x 12.51 x 8.77 inch (width/height/depth) overall dimensions of the modulator box. The modulator will only occupy the back section to a depth of eight inches. This back section will be divided into two levels, the upper level containing the two high voltage power supplies and fan, and the lower level containing the Extended Interaction Oscillator and the hard tube regenerative modulator. As of the end of the month, thirty percent completion has been attained.

Control Console

The control console has undergone approximately forty percent completion. All the printed circuit boards to be utilized in the control console have been assembled and are in the process of being installed. Faceplate design has been completed to ensure proper access to controls and front-end connections.

Physisch Laboratorium TNO
Page 2
27 August 1981

Financial Status

Expenditures on Contract 60/Dir/Eck in July were $10,360. Expenditures on the contract are thus approximately $40,960, leaving $7,038 on the contract as of 31 July 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

JCB:pmw

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

28 September 1981

Physisch Laboratorium TNO
Oude Waalsdorperweg 63
2597 AK's-Gravenhage
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 6 on Project A-2884, Contract 60/Dir/Eck Covering the Period 1 August to 31 August 1981

Gentlemen:

The results and current status of work performed on the subject contract during the referenced performance period are summarized below.

Control Console

The modulator control console has been completed and tested along with the connecting cables. Testing is being performed for a 115 V AC input voltage. (Only a jumper change is necessary to convert to 220 V AC operation.)

Modulator Unit Testing

After partial completion of the modulator assembly, testing was begun to ensure its proper operation. A number of difficulties were encountered which required partial redesign of the driver and tailbiter circuitry. The 15 kV high voltage power supply required to operate the pulse circuitry was tested first. The delivery of this power supply from the vendor was 2 months late. This made experimentation and development work possible only up to a voltage of 10 kV with a spare laboratory 10 kV high voltage power supply. The pulse circuits are required to operate up to 15 kV, and thus could not be fully tested.

A bias recharge circuit for the Y690 driver tube appears to be required at these higher voltages to ensure proper turn-off of the driver tube while the tailbiter circuit is in operation. This problem was not foreseen during the 10 kV tests.

The Y690 tailbiter may require an impedance matching network to ensure proper operation at 15 kV. This problem was not apparent previously during the 10 kV tests.

Both of the Y690 tube heat sink insulator-adaptors (SK-3064) will require a modification to increase their hold-off capabilities to 15 kV. The flashover point for this type of insulator appears to be approximately 10 kV, however, a solution for this problem has been suggested by the manufacturer. The catalog rating for this insulator is 15 kV.

After experiencing breakdown within the modulator circuitry, the EIO was removed and a dummy load substituted. Tests will be conducted to further locate and verify difficulties in high voltage sections of the modulator before reinstallation of the EIO.

Verification of proper operation of the EIO was carried out on a line type modulator owned by Georgia Tech with satisfactory results.

It is felt at this time that an additional month of time and an additional $7,123 will be necessary to complete the project. This has been formally transmitted to the Georgia Tech Contract Office and is in process at this time.

Financial Status

Expenditures on Contract 60/Dir/Eck in August were $7,436. Expenditures on the contract as of 1 September 1981 are thus approximately $45,860, leaving $2,138 on the contract as of 31 August 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-2884

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

19 October 1981

Physisch Laboratorium TNO
Oude Waalsdorperweg 63
2597 AK's-GRAVENHAGE
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Progress Report Number 7 on Project A-2884 under Contract No. 60/Dir/Eck Covering the Period 1 September 1981 to 30 September 1981

Gentlemen:

The results and current status of work performed during September are summarized below.

Modulator Unit Testing

Full voltage testing of the modulator was carried out in September. During the testing several problems were encountered as outlined in the request for modification of the contract dated 24 September 1981. The grid drive and biasing requirements for the regenerative driver stage resulted in unstable operation of the Y690A tube. Therefore, a grounded grid configuration using high voltage FET's as driver amplifiers was substituted which resulted in good circuit stability.

The elimination of the driver instability resulted in better matching between the Y690A tailbiter and the EIO. Good rise and fall time of the pulse is now being evidenced.

Power Supply

The modification of the driver to a grounded grid amplifier requires the addition of a +300 volt power supply. The modulator unit contains adequate space for mounting this power supply and a necessary current limiting circuit board.

EIO Operation

Initial tests to determine the proper Extended Interaction Oscillator (EIO) operation have been performed. RF measurements demonstrated the capability of adjustment of the pulse width between 60 and 120 ns. Good frequency stability during the pulse (15 MHz chirp) was exibited as observed as an oscilloscope using a high Q waveguide absorption frequency meter as a measurement standard.

Control Unit

Calibration of the front panel controls is now in progress and the system documentation is being upgraded to reflect the most recent circuit changes.

Financial Status

The expenditures for the month of September are $3,554 leaving a deficit of $1,416. This deficit and completion should be covered by the modification request dated 24 September 1981.

Respectfully submitted,

[redacted]

J. C. Butterworth
Project Director

Approved:

[redacted]

N. C. Currie, Chief
Radar Experimental Division

A-2884

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

24 November 1981

Physisch Laboratorium TNO
Oude Waalsdorperweg 63
2597 AK's-GRAVENHAGE
The Netherlands

Attention : Mr. J. G. den Breems

Subject : Monthly Contract Progress Report Number 8 on Project A-2884, Contract 60/Dir/Eck Covering the Period 1 October 1981 to 31 October 1981

Gentlemen:

The status of the technical and financial activities on the subject contract during the referenced time period are summarized below.

Technical Effort Status

The construction and testing of the 94 GHz modulator has been completed in accordance with the above referenced contract. Attachments 1 and 2 enclosed contain CRT photographs demonstrating the RF and high voltage pulse characteristics of the modulator.

Arrangements for acceptance testing and shipment are currently in progress with export and import papers being prepared.

Financial Statement

Expenditures on Contract 60/Dir/Eck in October were $8,878. Expenditures on the contract are thus $55,035, leaving zero funds in the contract as of 31 October 1981.

Respectfully,

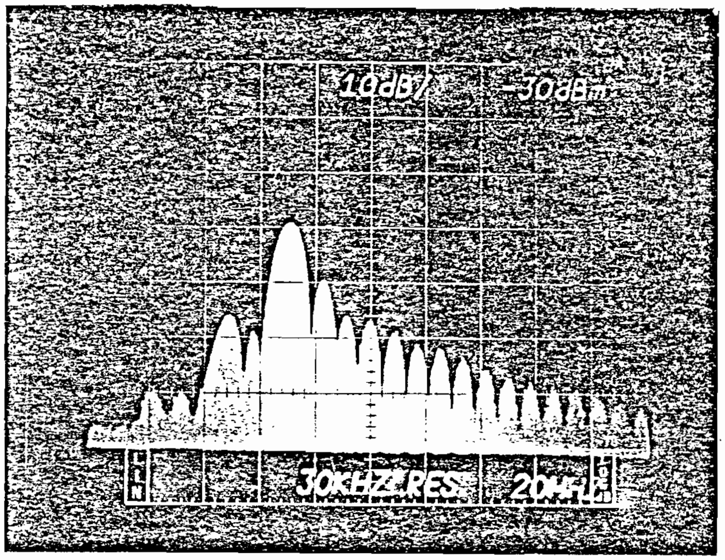
[redacted]

J. C. Butterworth
Project Director

Approved:

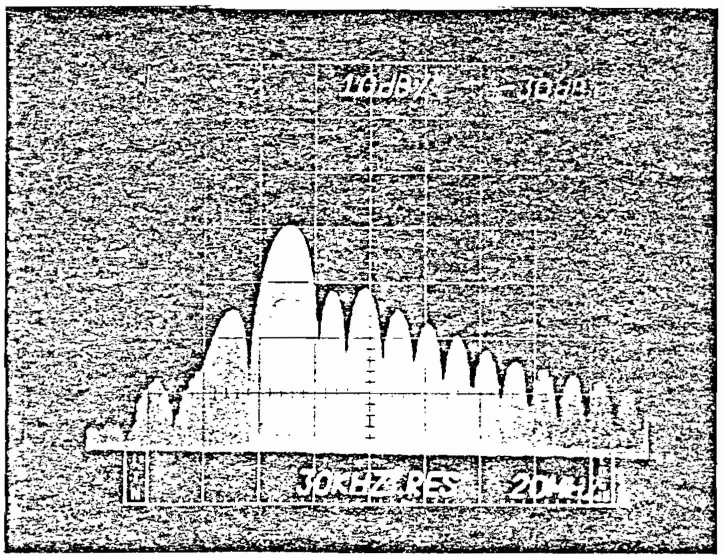
[redacted]

N. C. Currie, Chief
Radar Experimental Division

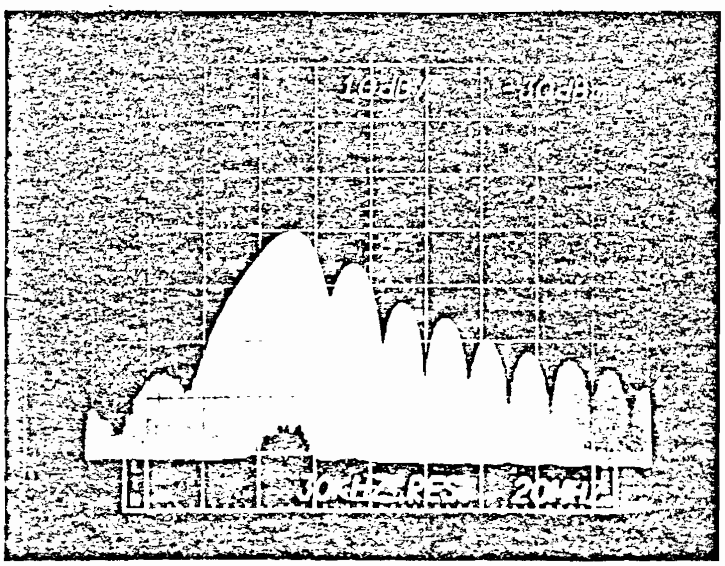


94 GHz EIO

130 ns



100 ns



65 ns

Attachment 1

Pulse Spectrum

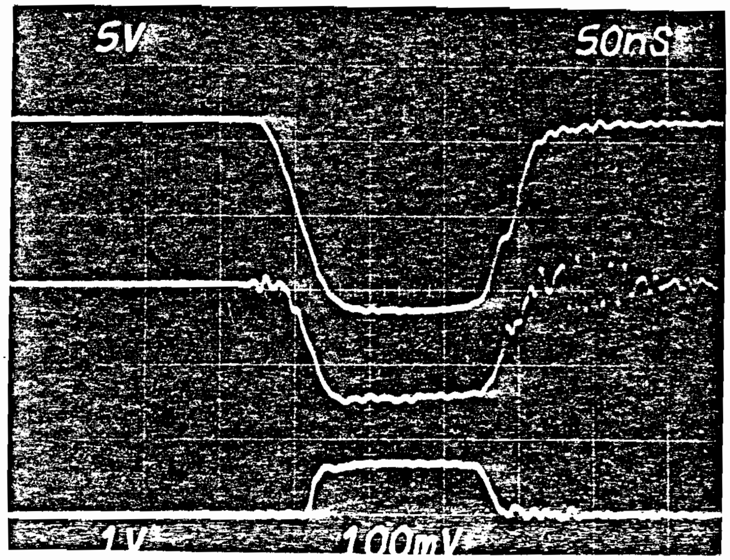


Figure 2. EIO Cathode Pulse @ 5KV/Div (top), Beam Current @ 1V/Div (middle), and RF output (bottom).

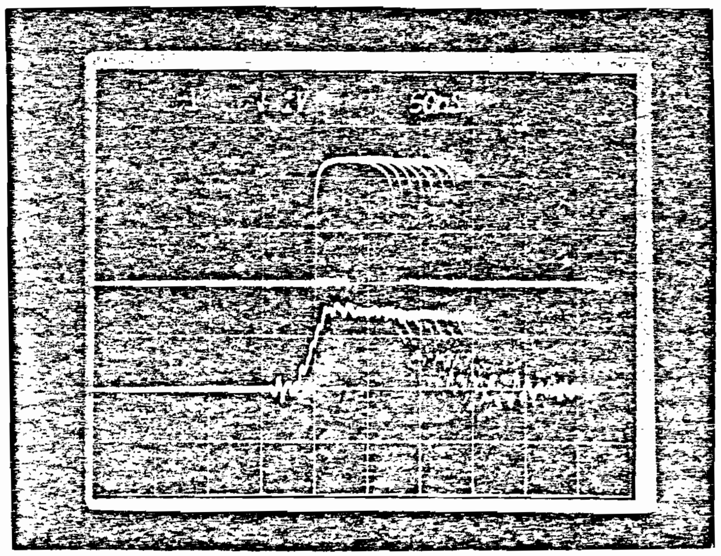


Figure 3. Multiple Exposure of EIO RF output pulse (top) and Beam Current (bottom) with high voltage probe disconnected.

A-2884

Final Report

GIT/EES Project No. A-2884
Contract No. 60/Dir/Eck

94 GHz EIO MODULATOR INSTRUCTION MANUAL

By

G. M. Conrad, J. C. Butterworth, D. S. Ladd, and J. C. Whitaker

Prepared for

TNO Physisch Laboratorium
Post Office Box 96864
2509 JG the Hague
The Netherlands

By

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

October 1981

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LIST OF FIGURES

SECTION I
GENERAL INFORMATION

WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES THAT ARE EXTREMELY DANGEROUS AND MAY BE FATAL.

EXTREME CAUTION MUST BE EXERCISED

1.1 SCOPE OF MANUAL

This manual describes the installation and operation of a modulator for a 94 GHz Extended Interaction Oscillator (EIO). This modulator employs a variable pulse width saturated driver circuit which delivers the required drive pulse to the EIO to generate radio frequency (RF) pulse having a minimum of frequency modulation, and fast rise and fall times that are required for a high resolution radar system. Section 2 describes the procedure for installing the control panel and modulator box. Section 3 contains operating instructions and procedures to ensure proper operation. Sections 4 and 5 contain descriptions of the circuits in the modulator and its mechanical construction. Appendix A contains a complete parts list. Appendix B includes schematic diagrams of the high voltage power supply control circuit modifications.

1.2 TRANSMITTER DESCRIPTION

The transmitter consists of the control console and the modulator box as described in Figure 1. A 21-pin connecting cable allows power and pulse width control signals to be passed from the control console to the modulator box. A rack mountable front panel control console provides access to appropriate control and monitor circuits and enables the operator to select pulse widths and high voltage levels. The modulator box contains two high voltage supplies, the driver circuit, and the EIO. The modulator box is to be mounted in a suitable location within the limits of the control cable and accessible to waveguide connections for the EIO.

Table 1 lists the modulator characteristics of the 94 GHz EIO modulator.

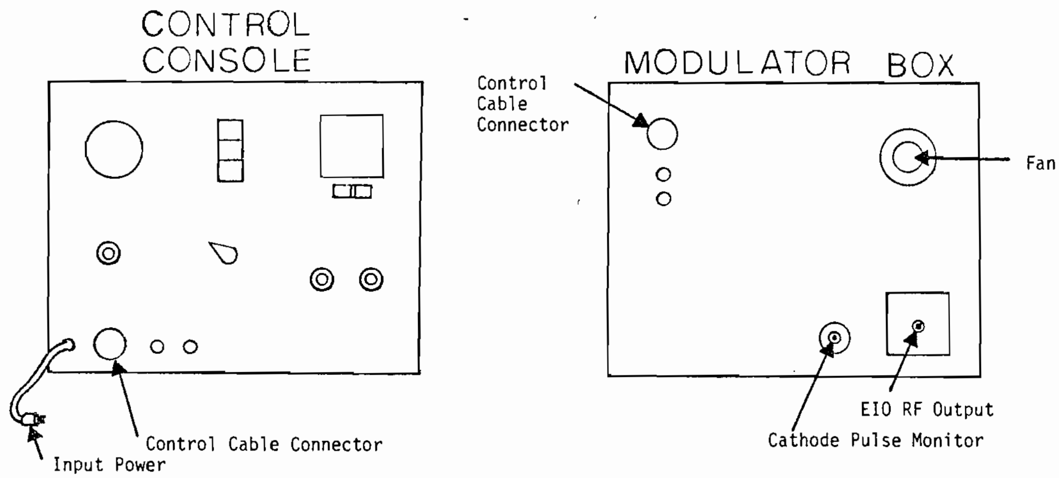


Figure 1. Complete Transmitter

TABLE 1. MODULATOR CHARACTERISTICS

PARAMETER	SPECIFICATION
Output Frequency	94 - 95 GHz
Output Power	1 kW
RF Pulse Width	65 - 130 ns
Maximum PRF	5 kHz
RF Pulse Rise and Fall Times	15 ns
Maximum Duty Factor	0.001
Input Power	220 VAC/110 VAC, 47 - 63 Hz or 28 V DC, 14 A

SECTION 2
INSTALLATION AND HOOK-UP

2.1 INSTALLATION

The control console is designed to be mounted in a standard 19-inch rack. The modulator box should be installed in the desired location within the limits of the 3 meter connecting cable. The cable is terminated with 21-pin connectors at each end.

2.2 HOOK-UP

Plug the cable connector in at each cable end. With the OFF/STANDBY/RADIATE switch in the OFF position, plug the AC line cord into a 220 VAC, 47 - 63 Hz, power outlet. It is possible to power the unit with 110 VAC by changing the jumper on the 28 V/14 A power supply in the control console or by using a separate 28 VDC/14 A power supply.

Locate the two BNC connectors on the modulator box. The CURRENT MONITOR connector will allow monitoring of the EIO peak collector current. The output should be terminated in a 50 Ω cable and load. The maximum observed voltage should be 1.8 V which represents 650 mA collector current for the EIO. (Refer to Varian TEST DATA FOR EXTENDED INTERACTION OSCILLATOR for the device being used). The calibration factor for the CURRENT MONITOR is 360 mA/V when terminated with a 50 Ω load. The INPUT PULSE connector is the input for the driver circuit and is approximately a 20 volts peak-to-peak positive-going pulse of the required PRF.

Locate the two BNC connectors at the control console. The TRIGGER IN connector is to input a TTL compatible positive-going pulse of the required PRF (less than 5 kHz) whose pulse width should be greater than 300 ns. The PULSE OUT connector is to connect a 50 ohm cable to the INPUT PULSE connector on the modulator box.

Locate the output flange of the EIO. Remove the plastic cover and connect the required waveguide to ensure proper power dissipation and a VSWR of less than 2.0.

SECTION 3

OPERATING INSTRUCTIONS

3.1 TURN ON PROCEDURE

a. Ensure that all connections as described in Section 2.2 are securely in place.

b. Set the High Voltage Anode and Pulse Controls on the control console to the desired position, i.e., -8.4 kV, +13.2 kV, for 94 GHz operation as determined in Varian TEST DATA FOR EXTENDED INTERACTION OSCILLATOR.

NOTE

The Anode and Beam voltage listed in the aforementioned test data is in reference to the CATHODE of the EIO. It is more appropriate to measure this voltage in reference to ground or body potential. Consequently, if it is assumed that CATHODE is at -21.6 kV with respect to ground (the negative BEAM VOLTAGE with respect to CATHODE), and the ANODE VOLTAGE is at -8.5 kV with respect to ground, then the PULSE VOLTAGE will be the voltage difference, -13.2 kV.

c. Turn OFF/STANDBY/RADIATE Switch to STANDBY position. The white ON light should turn on. A two minute delay will occur until the green STANDBY light energizes.

NOTE

With the green STANDBY light energized, the transmitter is ready for operation. If the OFF/STANDBY/RADIATE switch had been placed in RADIATE, the transmitter would commence radiating immediately upon completion of the 2 minute time delay.

d. Set the minimum-pointer to 0 μA on the BEAM CURRENT meter, and the maximum-pointer to 80 μA on the BEAM CURRENT meter.

e. Set the PULSE WIDTH to the desired position. This width defines the -3 dB power levels of the output RF from the EIO.

NOTE

The pulses driving the EIO are larger than the width of the RF pulses.

WARNING - DANGER HIGH VOLTAGE

f. If desired, place a Tektronix P 6015 high-voltage probe through the 1.5-inch hole into the red female banana jack. This is the EIO cathode voltage and should be monitored on a 100 MHz bandwidth oscilloscope.

g. Place the OFF/STANDBY/RADIATE switch to RADIATE. The red RADIATE light and RADIATE TIME counter will energize. If the EIO cathode voltage is being viewed, it should begin to rise and stabilize in approximately 3 seconds.

Pulsed RF should be present from the EIO at this time. If there is no RF at this point, refer to Principles of Operation (Section 4). Figure 2 illustrates the appropriate waveforms for the cathode voltage, collector current, and detected RF output. The high voltage test probe acts as a significant capacitive load and will degrade the quality of the RF pulse. The effect of varying the pulse width on the RF output pulse is illustrated in Figure 3. An expanded view of the RF output pulse rise and fall times is shown in Figures 4 and 5. Figure 6 illustrates the RF frequency spectrum of a 100 ns pulse with the high voltage probe disconnected.

3.2 OPERATING FEATURES

3.2.1 BEAM CURRENT METER

Once proper operation has been established, the maximum and minimum pointers for the beam current meter should be set for a small range of average beam current. If the duty factor of the peak beam current exceeds its nominal value, the BEAM CURRENT METER will indicate that the average collector current is too high. The control circuit will automatically switch to standby, turning off the high voltage power supplies, and the OVERLOAD light will energize. Appropriate steps such as reducing the

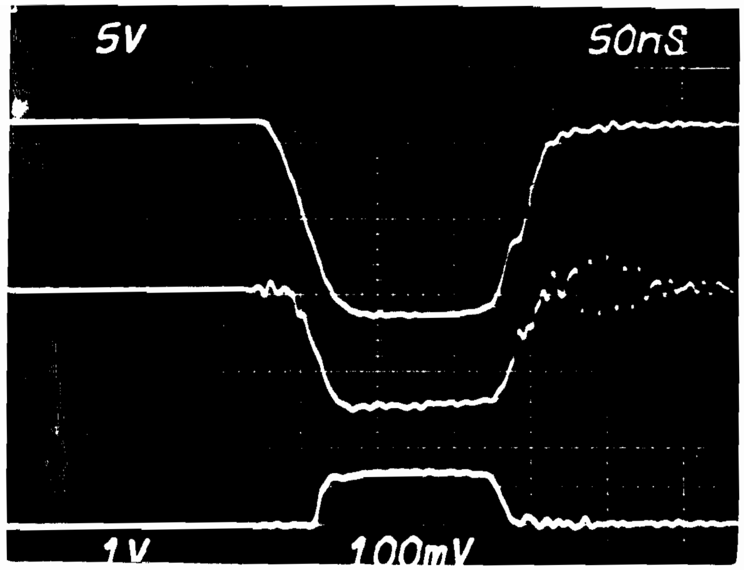


Figure 2. E10 Cathode Pulse @ 5KV/Div (top), Beam Current @ 1V/Div (middle), and RF output (bottom).

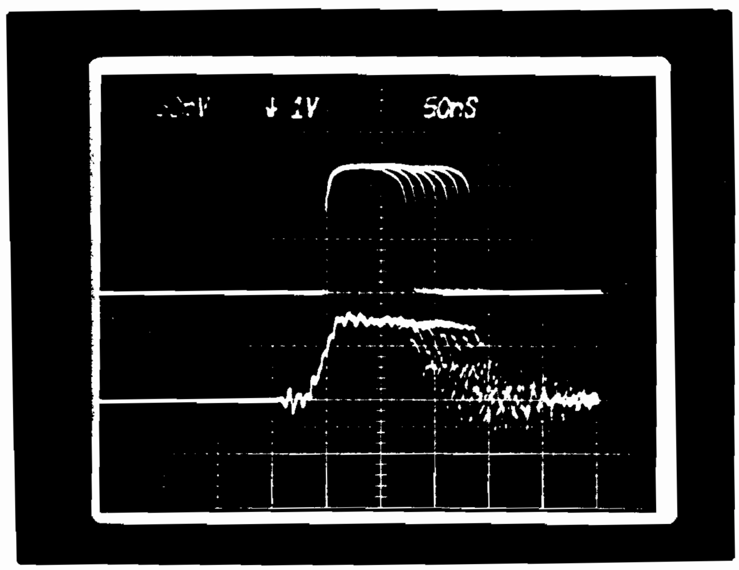


Figure 3. Multiple Exposure of E10 RF output pulse (top) and Beam Current (bottom) with high voltage probe disconnected.

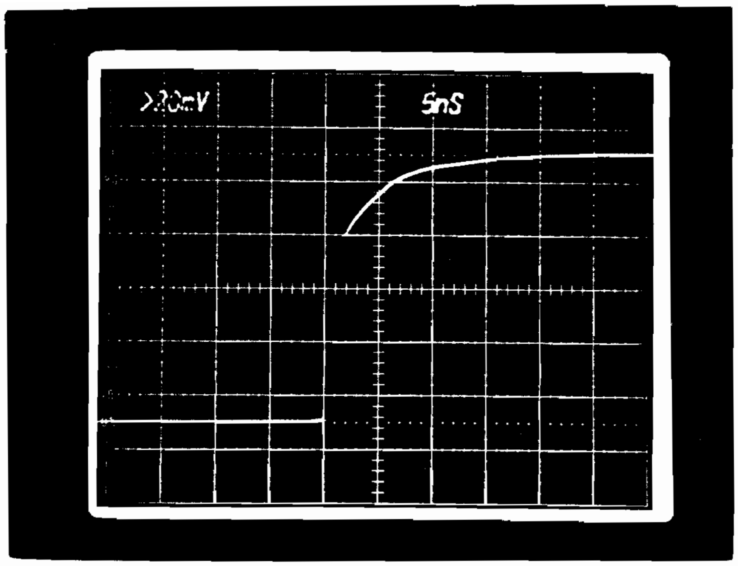


Figure 4. Expanded view of EIO RF output pulse rise time @ 5ns/Div.

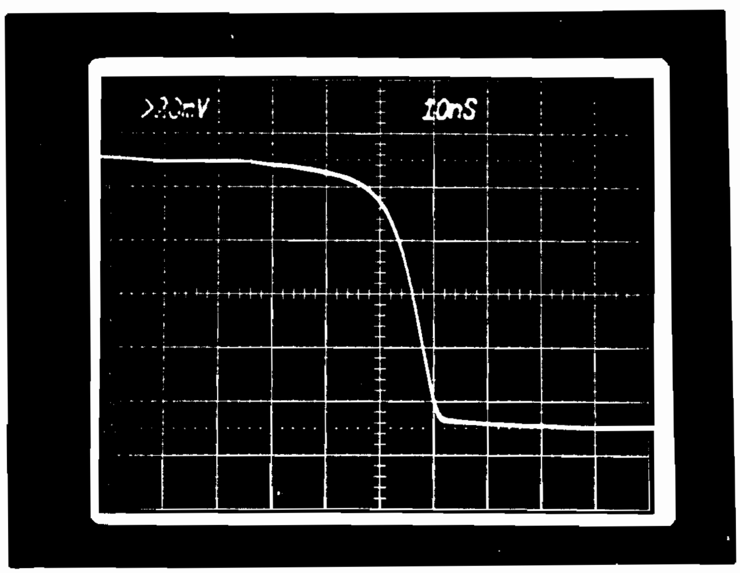


Figure 5. Expanded view of EIO RF output pulse fall time @ 10ns/Div.

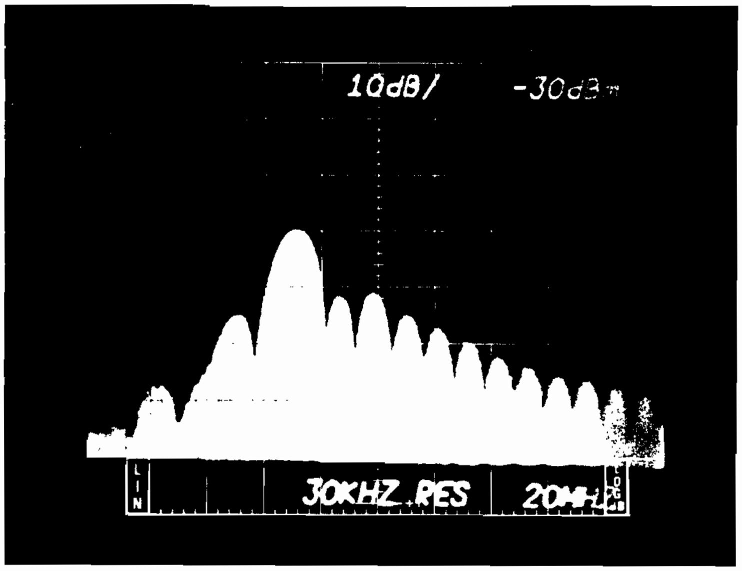


Figure 6. RF frequency spectrum of 100 ns pulse with high voltage probe disconnected.

PRF, pulse width, or peak beam current should be taken to reduce the average beam current. The OFF/STANDBY/RADIATE switch must be returned to STANDBY to cancel the OVERLOAD condition.

If the minimum-pointer for the BEAM CURRENT METER has been set to some value other than zero, the modulator will automatically switch to STANDBY when the average current decreases below this value. The overload circuit is not activated in this case. To switch to radiate once a lower limit has been set, turn the OFF/STANDBY/RADIATE switch to STANDBY and then back to RADIATE, or simply move the minimum-pointer below the new average current level.

3.2.2 RADIATE TIME METER

The RADIATE TIME meter records the total amount of time that the EIO has been in the radiate mode. The RADIATE TIME meter is not resettable. No provision has been made to measure the on time of the EIO heater. The meter runs when 28 V is supplied to the high voltage power supplies.

3.2.3 AUTOMATIC WARM-UP DELAY

A delay of 2 minutes has been built into the CONTROL CONSOLE to assure that the EIO and hard tubes have the proper warm-up time before high voltage is applied. A time delay relay on the control circuit board sets the minimum required time.

SECTION 4
PRINCIPLES OF OPERATION

4.1 GENERAL DESCRIPTION

The purpose of the modulator is to provide an RF pulse from the EIO in the range of 65 - 130 ns. An RF pulse with a minimum of frequency modulation is generated by supplying a flat top pulse to the cathode of the EIO. The flatness of this pulse is dependent entirely on the saturation characteristics of the driver tube.

4.2 CONTROL CIRCUITRY

The internal operation of the control circuitry is governed by five relays and a set of contacts inside the BEAM CURRENT meter. The meter and relays are de-energized when the modulator is in the off mode. The relay and meter contacts are shown in the off mode in the Control Console drawing, Appendix B.

When the OFF/STANDBY/RADIATE switch is set to STANDBY, relay K5 energizes, shorting contacts 1-3, supplying 220 VAC to the 28 VDC/14 A power supply. The output voltage of the 28 V DC power supply energizes relay K4, shorting contacts 1-3, thereby supplying 28 VDC to the $\pm$12 V power supply, the ON lamp, the delay relay, and relay K1. After a minimum of two minutes, the DELAY RELAY activates closing contacts 6-7 and 15-16. When contacts 15-16 on the DELAY RELAY are shorted out, the STANDBY lamp energizes.

The BEAM CURRENT meter must have power applied from the $\pm$12 VDC power supply to switch the internal contacts associated with the maximum and minimum settings on the front of the meter. Contacts 11-12 and 14-15 are normally closed when no over-maximum condition is present. Contacts 22-23 are normally closed when no under-minimum condition is present. The contacts are shown in the de-energized positions which correspond to over-maximum and under-minimum conditions.

When the OFF/STANDBY/RADIATE switch is set to RADIATE, relay K1 is held energized by current flowing through BEAM CURRENT meter contacts 22-23 and its own contacts 15-16. If the high voltage interlocks are all closed, relay K3 energizes, closing contacts 6-8 which supplies 28 VDC to the high voltage power supplies in the modulator. Relay K3 contacts 1-3 also close, energizing the radiate lamp and RADIATE TIME meter.

4.3 DRIVER STAGE

Refer to the Modulator drawing for the following description. The pulsed output of the control console is coupled via a 50 Ω coaxial cable to the pre-driver stage consisting of two VMOS FETs (VN99AK) which drive four VMOS power FETS (IVN6000). These drivers generate a high current pulse to drive the cathode of the planar triode V1 (Y690). The anode of the planar triode V1 is pulled down from approximately 13 kV to ground, producing a -13 kV pulse on the other side of the coupling capacitor C8 which is already biased -8 kV. Thus, the cathode of the EIO (V3) is pulsed to -21 kV. A current of approximately 15 A peak is required to charge the stray capacitance of the EIO to assure a fast rise time.

4.4 TAILBITER STAGE

Refer to the Modulator drawing for the following description. The tailbiter stage is a current controlled regenerative circuit. During the pulse, the current flowing through transformer T1 ensures at all times a negative bias on tailbiter tube V2. Once the negative pulse comes to an end, the current flowing towards the EIO to recharge its stray capacitance triggers the tube into conduction in a regenerative mode, thereby driving the cathode voltage back up to -8 kV in approximately 30 nanoseconds. Selection of resistor R24 is crucial in ensuring the amount of negative bias required during the pulse to prevent the tailbiter from turning on early.

4.5 COLLECTOR CURRENT MONITOR

Refer to the Modulator drawing for the following description. The printed circuit board for the collector current monitor is located above the EIO. It performs two functions associated with collector current. A 2:19 turns ratio transfomer supplies the 50Ω CURRENT MONITOR output. This output requires a 50 Ω termination for correct calibration as discussed in Section 2.2. Capacitors C1 and C2 allow a path for the AC portion of the pulse current. The average DC current path exists through the bilfilar would inductor and the BEAM CURRENT METER. R28, R29, R30 are shunt resistors to calibrate the meter for 500 mA full scale deflection.

4.6 HEATER SUPPLY

Refer to Heater Power Supply drawing for the following description. The heater supply to both Y690 tubes and the EIO consists of approximately 14 volts peak-to-peak

AC supplied by a Royer Oscillator circuit. A toroidal core with teflon insulation material makes up a low capacitance coupler between the oscillator and all three tubes. The oscillator frequency is approximately 12 kHz.

The Heater Supply printed circuit board is located in the modulator and is supplied by 28 VDC when the OFF/STANDBY/RADIATE switch is set to STANDBY. The LM 223 regulator allows the output voltage to the filaments to be set at 6.3 V RMS. Transistors Q1 and Q2 turn on and off, dependent on the saturation characteristics of the tape wound transformer T2 due to the feedback provided by winding N3 on transformer T1. The EIO heater voltage is set to 6.30 V RMS, leaving both the hard tube filament voltages about 0.1 V RMS higher.

4.6.1 HEATER SUPPLY CIRCUIT

Transformer T2 on the Heater Supply circuit board also produces a small voltage on winding S3 which is amplified by the darlington pair Q3/Q4 which energizes relay K1, closing another high voltage interlock. This safety circuit is intended to prevent EIO cathode damage the in the event of Heater Supply failure while the modulator is in operation.

4.7 300 V POWER SUPPLY CURRENT LIMITER

Refer to the Modulator drawing for the following description. In the event of failure of one of the four power VMOS FETs (IVN6000), the 300 V power supply output would be shorted to ground, damaging the power supply. Consequently, a current limiter consisting of transistor Q7 is placed in series with the output of the power supply to limit the amount of current out of the power supply to a safe value. Transistor Q9 provides a constant current source to the base of transistor Q7. Transistor Q8 turns on when the output is shorted due to the voltage generated across the 27 ohm emitter resistor (R18) of transistor Q7. This shorts the base current to transistor Q7 to ground, thereby cutting off transistor Q7 and consequently reducing the output current to a safe value.

4.8 HIGH VOLTAGE POWER SUPPLY MODIFICATIONS

Refer to Appendix B for the schematic diagrams of the control circuitry for the 15 kV and -10 kV high voltage power supplies.

During turn-on, both power supplies were found to overshoot the maximum allowable output voltage by approximately 20%. To solve this problem, a 10 μf capacitor was added to the reference voltage circuit to create approximately a three-second startup time with no overshoot. In addition, to ensure this capacitor was fully discharged when going to STANDBY on the OFF/STANDY/RADIATE switch, a diode (IN914) was added to discharge this capacitor.

For external control of the high voltage, the variable resistor RP 1 was removed from the original units, and a modified resistor network arrangement was placed in the CONTROL CONSOLE. These changes are shown in Appendix B diagrams.

SECTION 5
MECHANICAL DESCRIPTION

5.0 EIO MOUNTING

The Extended Interaction Oscillator is mounted in the modulator box by means of four screws. Care must be exercised in mounting the EIO to prevent physical damage to the body and waveguide section. Removal is accomplished by leaving the EIO attached to the 1/4 inch aluminum plate, unscrewing the plate on all four sides, and sliding the EIO and plate out the back end after removing the bottom angle bracket. The leads to the EIO must then be unsoldered prior to first removal.

5.2 MODULATOR BOX

The modulator box is divided into an upper and lower level. The upper level contains the fan, 300 VDC supply, and High Voltage power supplies. The lower level contains the driver circuit, heater supply circuit, tailbiter circuit, and EIO. The circulation path for air is into the fan, across the upper level, down to the lower level, across the lower level, and out through the high voltage probe and EIO access holes. All panels must be in place to ensure proper cooling. The box has been constructed of 1/8 inch aluminum panels fastened together by 6-32 screws and angle brackets.

Access to the modulator is most easily attained by removal of the rear panel. Removing this panel will open a high voltage interlock switch, however, it is of the type that can be bypassed by pulling the plunger out approximately 1/4 inch. Always use a grounding stick to discharge all high voltage parts before touching them. Operation of the modulator when the panel is removed requires external cooling of the high voltage section.

5.3 CONTROL CONSOLE

The CONTROL CONSOLE is divided into an upper and lower level. The upper level contains the 220 VAC to 28 VDC power supply, relays, ± 12 VDC power supply, fan, and the beam current meter. The lower level contains the pulse generator board to drive the pre-driver and the high voltage adjust resistive network. Access into the control console is by means of the upper or lower covers. Air flow is only required in the upper level to cool the 28 VDC power supply.

APPENDIX A

PARTS LIST

APPENDIX A

CONTROL MODULE:

R_1, 68 Ω /1/2 W
R_2, 10 k Ω /1/4 W
R_3, 1 k Ω /1/4 W
R_4, 1 k Ω /1 W
R_5, 68 Ω /1/2 W
R_6, 100 Ω /1/2 W
R_7, 100 Ω /1/2 W
R_8, 2.2 k Ω /1/2 W
R_9, 47 Ω /1/2 W
R_{10}, 47 Ω /1/2 W
R_{11}, 100 Ω /1/2 W
R_{12}, 10 k Ω ,trimpot
R_{13}, 47 Ω 1/4 W
R_{14}, 3.3 k Ω /1/4 W
R_{15}, 2.2 k Ω /1/4 W
R_{16}, 15 Ω /1/4 W
R_{17}, 1 k Ω /1/4 W
R_{18}, 10 k Ω /potentiometer
R_{19}, 8.3 k Ω /1/4 W
R_{20}, 10 k Ω /potentiometer
R_{21}, 22 k Ω /1/4 W
R_{22}, 2.94 k Ω /1/4 W
R_{23}, 10 k Ω /potentiometer
R_{24}, 11.5 k Ω /1/4 W
R_{25}, 15 k Ω /1/4 W

C_1, 220 μ F/63 V
C_2, 10 μ F/25 V
C_3, 100 μ F/20 V
C_4, 100 μ F/63 V
C_5, 47 μ F/6 V
C_6, 47 μ F/6 V
C_7, 1 μ F/47 V
C_8, 100 PF
C_9, 5 PF
C_{10}, 1 μ F/47 V
C_{11}, 1 μ F/47 V
C_{12}, 6.8 μ F/50 V
C_{13}, 6.8 μ F/50 V
C_{14}, 6.8 μ F/50 V

Q_1, 2N4403
Q_2, 2N4401
Q_3, 2N6661

D_1, 1N4004
D_2, 1N4004

CONTROL MODULE (Continued)

D_3, 1N4004
D_4, 1N4004
D_5, 1N4004
D_6, 1N4759

U_1, 74121
U_2, 74121
U_3, 745140
U_4, LM34015 V
U_5, LM317

T_1, PR-6503-1
T_2, PR-6503-1
L_1, 1 turn on ferrite bead
L_2, 1 turn on ferrite bead

M1, Simpson meter relay, model 3323

K_1, 24 VDC, 4 PDT, W67CSX-8, Magnecraft
K_2, 24 VDC, delay relay, DPDT, W67CPSOX-4, Magnecraft
K_3, 24 VDC, W88CPX-7, Magnecraft
K_4, 24 VDC W88CPX-7, Magnecraft
K_5, 220 VAC, W88ACPX-32, Magnecraft

DS1, 28 V lamp, CM313
DS2, 28 V lamp, CM313
DS3, 29 V lamp, CM313
DS4, 28 V lamp, CM1829
DS5, 28 V lamp, CM1820

F1, 3 AG/10 A, fuse
F2, 3 AG/10 A, fuse
L_3, Ferrite bead

HEATER POWER SUPPLY

R_1, 100 Ω/2 W
R_2, 100 Ω/2 W
R_3, 150 Ω/2 W
R_4, 100 Ω/1 W trimpot
R_5, 27 Ω/1/2 W
R_6, 10 Ω/2 W
R_7, 10 Ω/1/2 W
R_8, 10 Ω/1/2 W
R_9, 3.9 k Ω/1/4 W

C_1, 1 μF/50 V

HEATER POWER SUPPLY (Continued)

C_2, 10 μ F/25 V
C_3, 0.1 μ F/16 V
C_4, 0.025 μF

D_1, 1N914
D_2, 1N751A
D_3, 1N4002

Q_1, 2N5882
Q_2, 2N5882
Q_3, 2N4401
Q_4, 2N3440

U_1, LM223K

T_1, Siemens, R58-N30, N_1 & N_2 -10T #20, N_3 & N_4 & N_5 -3T #20
T_2, Mag Inc., -80614-ID(MA), S_1 & S_2 &S_3 & S_4 -21T #30

MODULATOR

R_1, 47 Ω , 1/4 W
R_2, 15 Ω , 1/4 W
R_3, 15 Ω , 1/4 W
R_4, 15 Ω , 1/4 W
R_5, 15 Ω , 1/4 W
R_6, 500 Ω , 1/4 W
R_7, 15 Ω , 1/4 W
R_8, 15 Ω , 1/4 W
R_9, 15 Ω , 1/4 W
R_{10}, 15 Ω , 1/4 W
R_{11}, 50 M Ω , 7.5 W
R_{12}, 2 x 1 Ω In Parallel
R_{13}, 2 x 1 Ω In Parallel
R_{14}, 2 x 1 Ω In Parallel
R_{15}, 2 x 1 Ω In Parallel
R_{16}, 68 Ω /2 W
R_{17}, 1 k Ω /1/4 W
R_{18}, 27 Ω /1/4 W
R_{19}, 1.5 k Ω /1/4 W
R_{20} 35 k Ω /7.5 W
R_{21}, 33 k Ω /1/4 W
R_{22}, 220 k Ω /1/2 W
R_{23}, 15 k Ω /1/4 W
R_{24}, 200 Ω /1/4 W
R_{25}, 30 M Ω 7.5 W
R_{26}, 30 M Ω /7.5 W
R_{27}, 47 Ω /1/4 W

MODULATOR (Continued)

R_{28}, 150 Ω/1/4 W
R_{29}, 470 Ω/1/4 W
R_{30}, 910 Ω/1/4 W
R_{31}, 47 Ω/1/4 W
R_{32}, 100 k Ω/1 W
R_{33}, 1 k Ω/1/4 W
R_{34}, 100 k Ω/1 W

C_1, 0.001 μF/1 kV
C_2, 1 μ F/50 V
C_3, 1 μ F/50 V
C_4, 0.01 μ F/20 kV
C_5, 0.1 μF/600 V
C_6, 0.1 μF/16 V
C_7, 1 μ F/220 V + 0.1 μ F/250 + 0.01 μ F/1 kV
C_8, 2500 μ F/30 kV
C_9, 0.01 μ F/10 kV
C_{10}, 0.1 μ F/16 V
C_{11}, 0.1 μ F/16 V
C_{12}, 0.1 μ F/50 V
C_{13}, 6.8 μ F/50 V
C_{14}, .22 μ F/200 V
C_{15}, .001 μ F/200 V

L_1, Ferrite Bead
L_2, Ferrite Bead
L_3, Ferrite Bead Bifilar Winding
L_4, 5 Turns Bifilar #23 AWG on B64290-A0045 Permag Toroid Core

T_1, 8 Turns Trifilar #23 AWG on BBR 7727
T_2, 2:19 #16 AWG: #30 AWG

Q_1, VN99AK VMOS FET
Q_2, VN99AK VMOS FET
Q_3, IVN6000 VMOS FET
Q_4, IVN6000 VMOS FET
Q_5, IVN6000 VMOS FET
Q_6, IVN6000 VMOS FET
Q_7, 2N6308
Q_8, 2N4401
Q_9, 2N3439

D_1, IN4759
D_2, IN4759
D_3, IN4938
D_4, IN5384
D_5, IN4728
D_6, IN5383
D_7, IN5383

MODULATOR (Continued)

D_8, SCH15000
D_9, IN5383
D_{10}, IN5383
D_{11}, IN5383

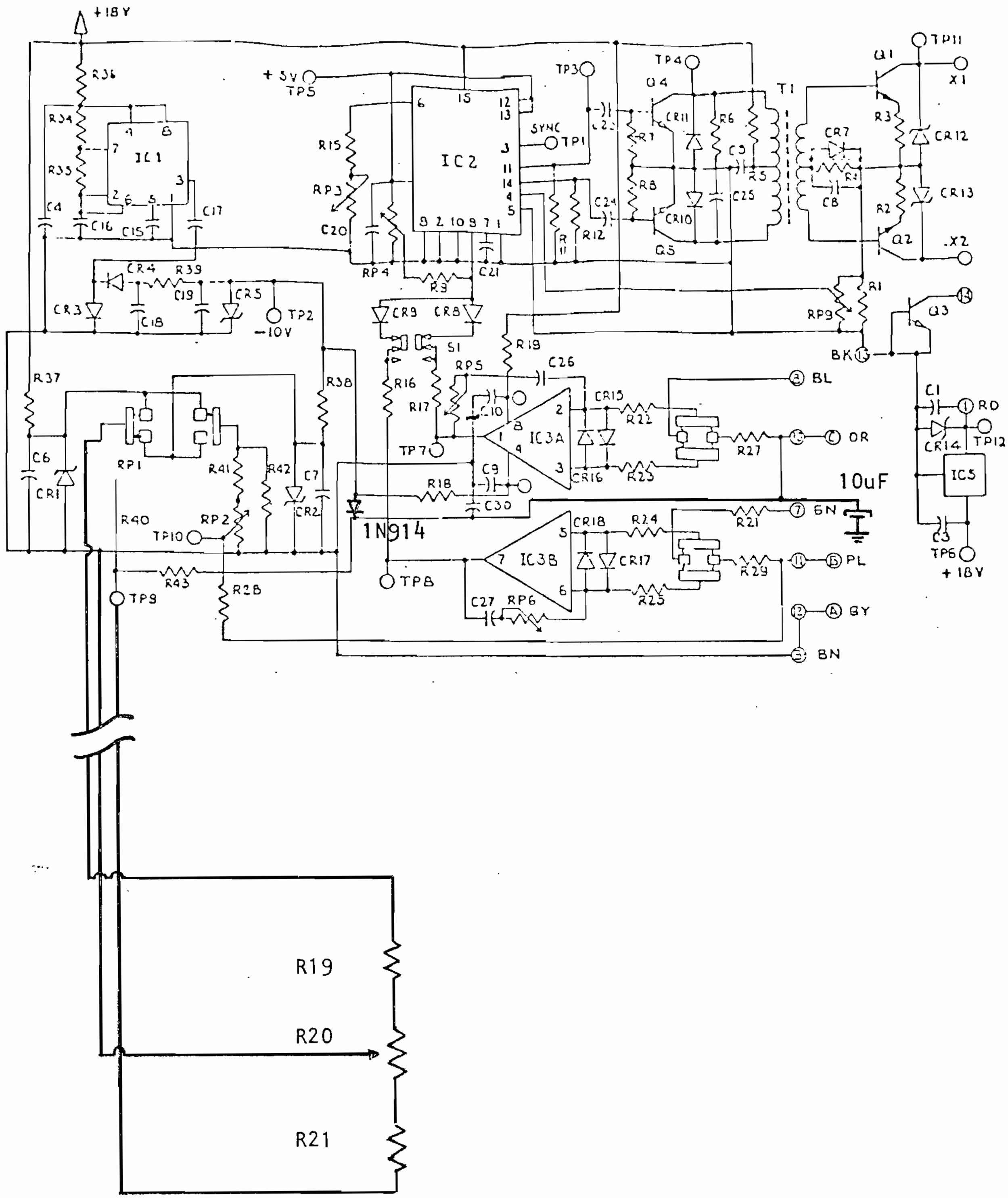
V_1, Y690 Planar Triode
V_2, Y690 Planar Triode
V_3, EIO Model No. VKB 2443MI Serial No. E0271MO

P_1, 300 V/10 W Technetics Power Supply
P_2, NRL 672-01, 10 kV Advanced High Voltage Company
P_3, NRL 1337, 15 kV Advanced High Voltage Company
P_4, Heater Power Supply (see drawing)

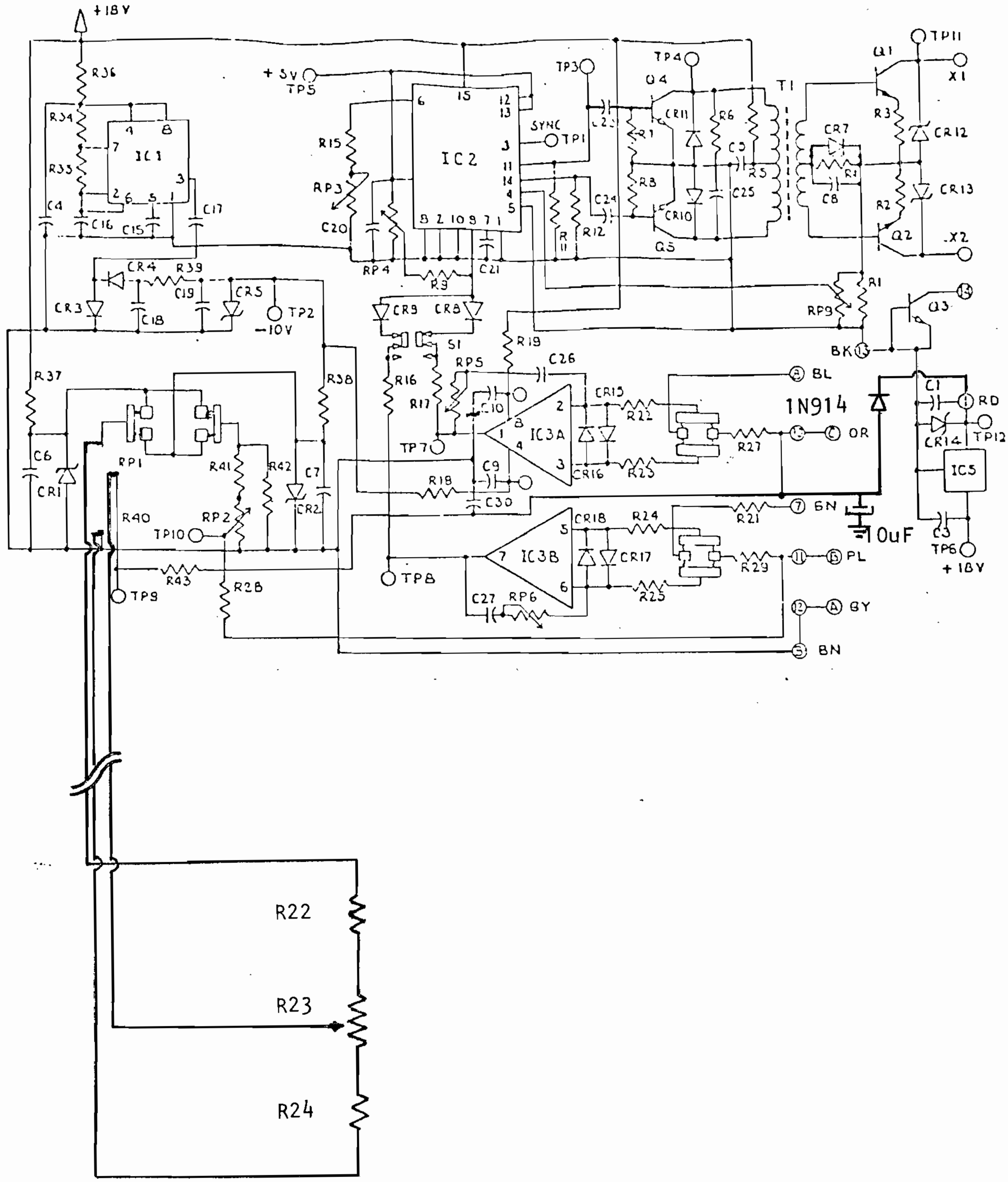
K_1, Relay RHS17D11 Potter and Brumfield

APPENDIX B

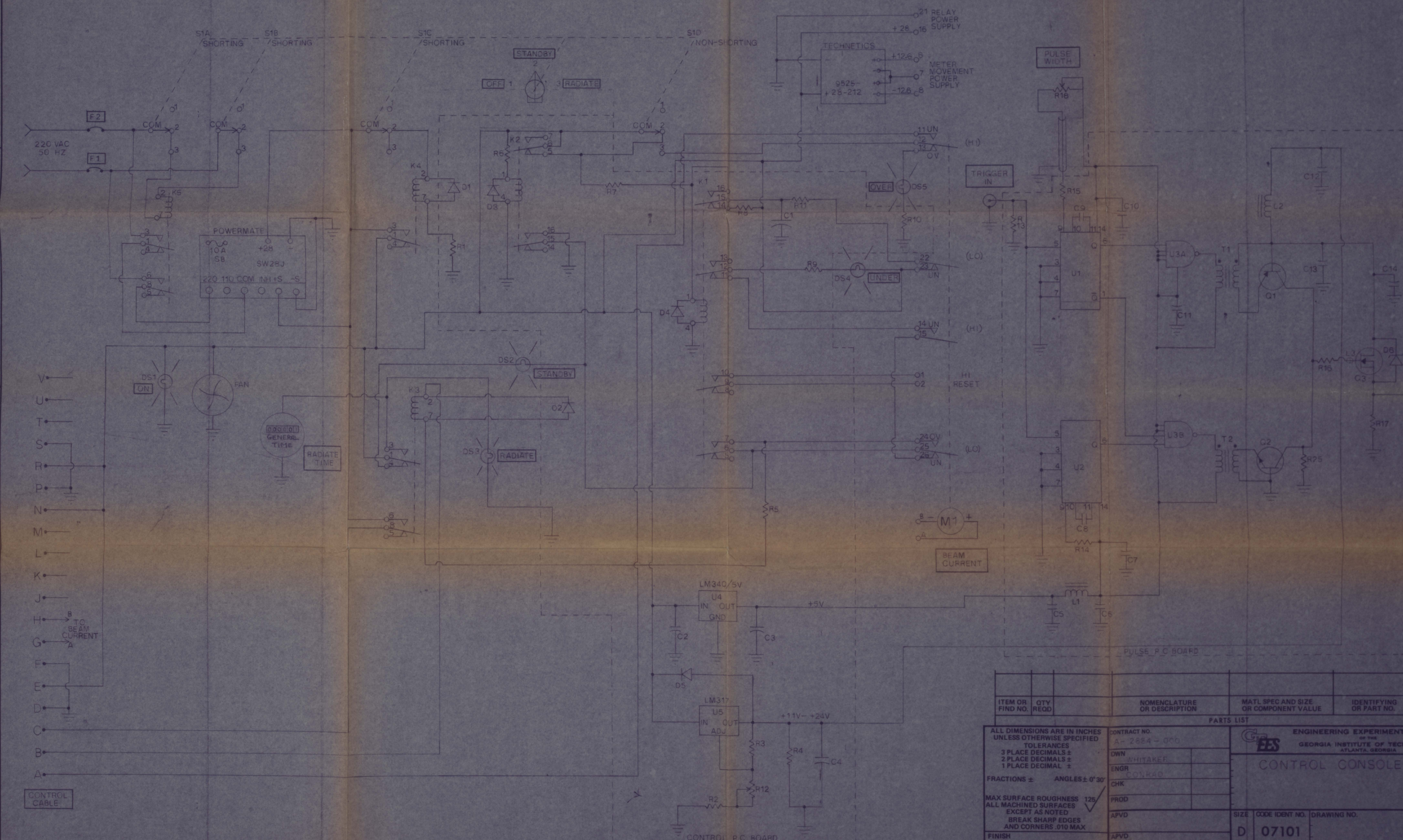
SCHEMATIC DIAGRAMS



-10 KV High Voltage Power Supply Modifications



15 KV High Voltage Power Supply Modifications



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ITEM OR FIND NO.	QTY REQD	NOMENCLATURE OR DESCRIPTION	MATL SPEC AND SIZE OR COMPONENT VALUE	IDENTIFYING OR PART NO.	CODE IDENT.

PARTS LIST

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMAL ±
FRACTIONS ± ANGLES ± 0°30'
MAX SURFACE ROUGHNESS 125 ALL MACHINED SURFACES EXCEPT AS NOTED
BREAK SHARP EDGES AND CORNERS .010 MAX
FINISH

CONTRACT NO. A-2884-000
DWN WHITAKER
ENGR CONRAD
CHK
PROD
APVD
APVD

EES ENGINEERING EXPERIMENT STATION OF THE GEORGIA INSTITUTE OF TECHNOLOGY ATLANTA, GEORGIA

CONTROL CONSOLE

SIZE	CODE IDENT NO.	DRAWING NO.	REV
D	07101		

SCALE SHEET

APPLICATION		
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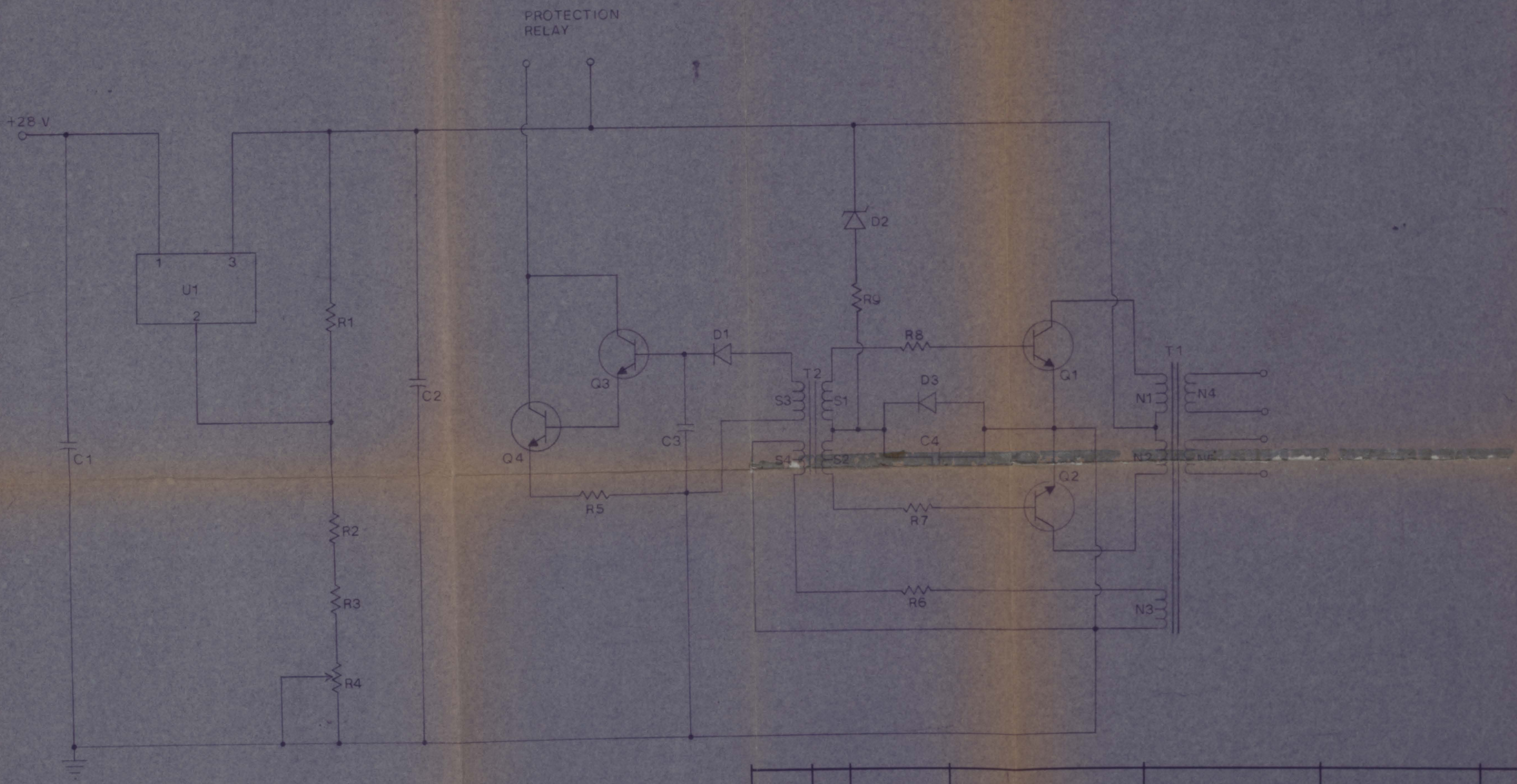

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ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMAL ±
FRACTIONS ± ANGLES ± 0° 30'
MAX SURFACE ROUGHNESS 125 ALL MACHINED SURFACES EXCEPT AS NOTED
BREAK SHARP EDGES AND CORNERS .010 MAX
FINISH

CONTRACT NO. A-2884-000		
DWN	WHITAKER	9-29-81
ENGR	CONRAD	
CHK		
PROD		
APVD		
APVD		

ENGINEERING EXPERIMENT STATION OF THE GEORGIA INSTITUTE OF TECHNOLOGY ATLANTA, GEORGIA

HEATER POWER SUPPLY

SIZE	CODE IDENT NO.	DRAWING NO.	REV
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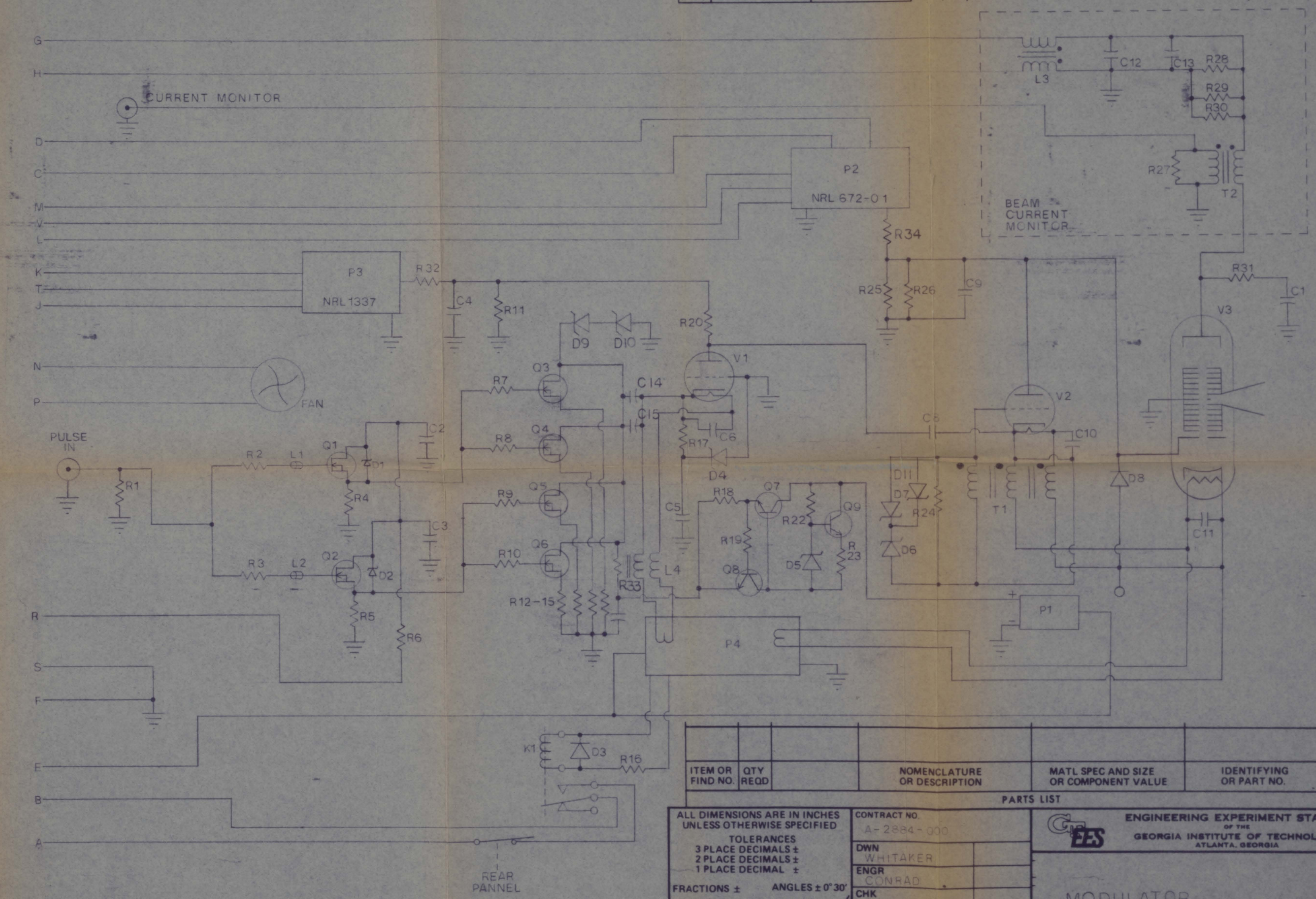
SCALE		SHEET	



APPLICATION		
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REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVED

PARTS LIST

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ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMAL ±
FRACTIONS ± ANGLES ± 0°30'
MAX SURFACE ROUGHNESS 125 ALL MACHINED SURFACES EXCEPT AS NOTED
BREAK SHARP EDGES AND CORNERS .010 MAX
FINISH

CONTRACT NO. A-2884-000
DWN WHITAKER
ENGR CONRAD
CHK
PROD
APVD
APVD

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MODULATOR

SIZE C | CODE IDENT NO. 07101 | DRAWING NO. | REV
SCALE | SHEET